

MULTIMEDIA



UNIVERSITY

STUDENT ID NO

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# MULTIMEDIA UNIVERSITY

## FINAL EXAMINATION

TRIMESTER 2, 2018/2019

### ETM2016 – ANALOG COMMUNICATIONS ( TE )

7 MARCH 2019  
9.00 a.m. – 11.00 a.m.  
( 2 Hours )

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#### INSTRUCTIONS TO STUDENTS

1. This question paper consists of 10 pages with 4 Questions only.
2. Attempt **ALL** questions. Each question carries an equal total mark and the mark distribution for each question is given.
3. Please write all your answers in the Answer Booklet provided.

**Question 1**

- (a) A sinusoidal voltage  $E \sin \omega t$ , where  $t$  is time, is passed through a half-wave rectifier that clips the negative portion of the wave shown in Figure Q1.1. Find the Fourier series of the resulting periodic function. The formula is

$$u(t) = \begin{cases} 0 & \text{if } -\tau < t < 0, \\ E \sin \omega t & \text{if } 0 < t < \tau \end{cases} \quad \tau = \frac{\pi}{\omega}$$

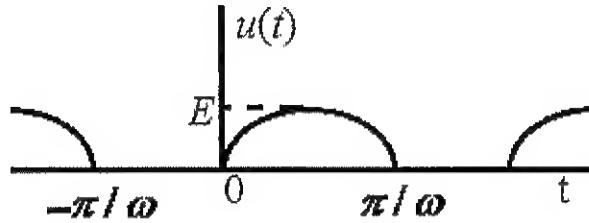


Figure Q1.1

[10 marks]

- (b) Figure Q1.2 shows the plot of the Inverse Fourier Transform of  $S(f)$  given by

$$s_m(t) = (A_c + A_x \cos(2\pi f_x t)) \cos(2\pi f_c t)$$

- (i) What is the value of the frequency  $f_c$ ? [2 marks]
- (ii) What is the value of the frequency  $f_x$ ? [2 marks]
- (iii) Calculate  $A_c$  and  $A_x$ . [4 marks]

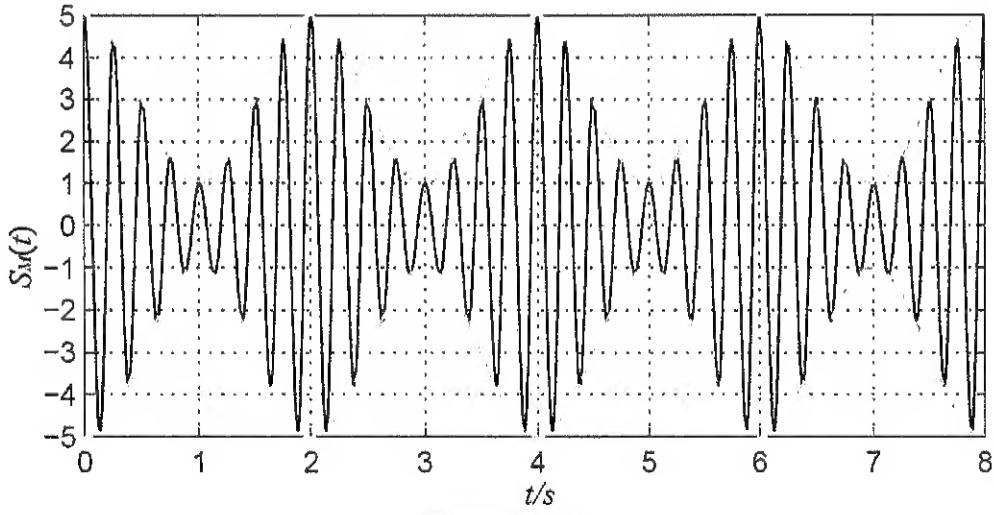


Figure Q1.2

**Continued...**

- (c) Figure Q1.3 shows the amplitude spectrum of frequency domain signal  $Y(\omega)$ .
- (i) Determine the values of the frequencies at  $\omega = 90 \text{ rad/s}$ ,  $\omega = 100 \text{ rad/s}$  and  $\omega = 110 \text{ rad/s}$ . [3 Marks]
- (ii) Convert  $Y(\omega)$  into its equivalent time domain signal  $y(t)$  where  $\theta_n = 0$  for all  $n$ . [4 Marks]

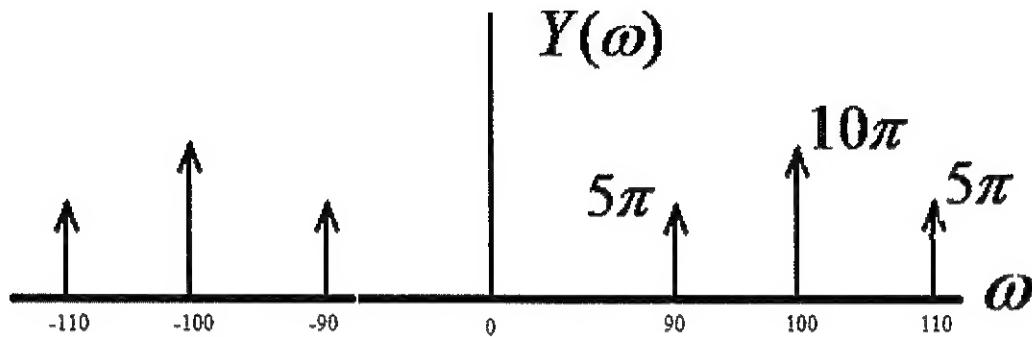


Figure Q1.3

Continued...

## Question 2

- (a) An angle modulated signal has the form

$$u(t) = 100 \cos[2\pi f_c t + 4 \sin 2\pi f_m t]$$

where  $f_c = 10$  MHz and  $f_m = 1000$  MHz

- (i) Assume that this is an FM signal; determine the modulation index and the transmitted signal bandwidth.

[3 Marks]

- (ii) Assuming that this is a PM signal determine the modulation index and the transmitted signal bandwidth.

[3 Marks]

- (b) Balanced modulator is used to generate double-sideband suppressed-carrier modulation (DSB-SC) signal. With a suitable block diagram, discuss how to generate a DSB-SC signal. Please aid your answer with complete mathematical derivation.

[13 Marks]

- (c) The tone modulation double-sideband large carrier (DSB-LC) AM waveform is given by

$$\varphi(t) = (A - 5 \cos 100t) \cos 1000t$$

The power efficiency of the system is 1/19.

- (i) Determine A

[3 Marks]

- (ii) Sketch the magnitude spectrum of  $\varphi(t)$ .

[3 Marks]

**Continued...**

### Question 3

- (a) An angle modulated signal is given as below

$$\varphi_{EM}(t) = 10 \cos(2\pi \cdot 10^5 t + 2 \sin 2\pi 2000 t)$$

It is input to a frequency multiplier with a factor  $N = 5$  to produce the FM signal  $y(t)$ .

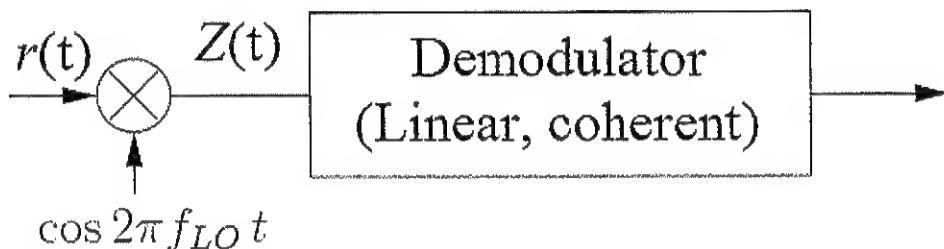
- (i) Define in words the frequency deviation and determine its value.

[2+4 Marks]

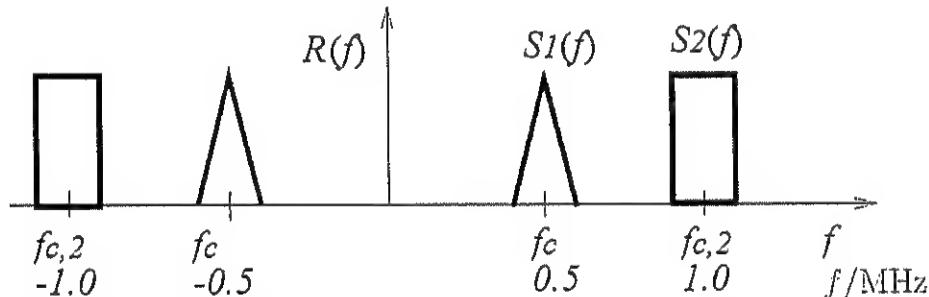
- (ii) Estimate the bandwidth, as per Carson's rule, of the signal  $y(t)$ . Is this narrowband FM?

[2+1 Marks]

- (b) We want to receive a medium wave signal  $s_1(t)$  transmitted at carrier frequency  $f_c = 0.5$  MHz. The system proposed in Figure Q3.1 first down-converts the received signal  $r(t)$  to a constant intermediate frequency  $f_{IF} = 0.25$  MHz. Then the signal is demodulated. The frequency of the local oscillator is  $f_{LO} = 0.75$  MHz.



$r(t)$  consists of our desired signal  $s_1(t)$  and an interfering signal  $s_2(t)$  with the same bandwidth as  $s_1(t)$  at carrier frequency  $f_{c,2} = 1.0$  MHz. The spectra are given in Figure Q3.2.



Sketch the spectrum  $Z(f)$  of the signal  $z(t)$  at the output of the down converter. Label the frequency axis only.

[6 Marks]

- (c) With the aid of a block diagram, describe the process of FM-to-AM conversion in demodulating an FM signal.

[10 Marks]

Continued...

### Question 4

- (a) Based on the following properties of an FM signal generation:
- The carrier frequency is 1 MHz and the power of the FM signal is 50 W,
  - The modulating signal  $m(t) = 4 \cos(2\pi 100t)$ ,
  - The frequency deviation constant is  $500\pi$  rad/sec/volt,
- (i) Determine the modulation index.  
(ii) Find the power and the bandwidth using Carson's rule and Bessel Function [12 Marks]
- (b) A certain communication channel is characterized by 90dB attenuation and additive white noise with power-spectral density of  $N_0/2 = 0.5 \times 10^{-14}$  W/Hz. The bandwidth of the message signal is 1.5 MHz and its amplitude is uniformly distributed in the interval  $[-1, 1]$ . If we require that the transmitter power 15kW, find the signal to noise ratio (SNR) after demodulation. Express the SNR in dB. [8 Marks]
- (c) A single sideband modulated received signal  $S_{BP}(t)$  shall be demodulated with a heterodyne receiver. The magnitude spectrum  $|S_{BP}(f)|$  of  $S_{BP}(t)$  is shown in **Figure Q4.1**.

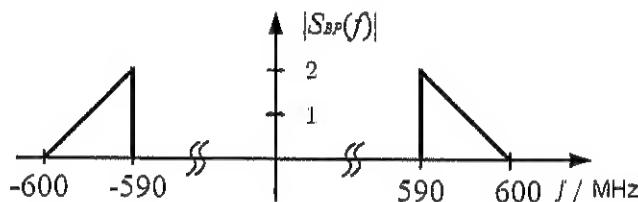


Figure Q4.1

**Figure Q4.2** shows the structure of the heterodyne receiver. The frequency of the first mixer is given by  $f_{LO} = 450$  MHz and the frequency of the second mixer is given by  $f_{IF} = 150$  MHz.

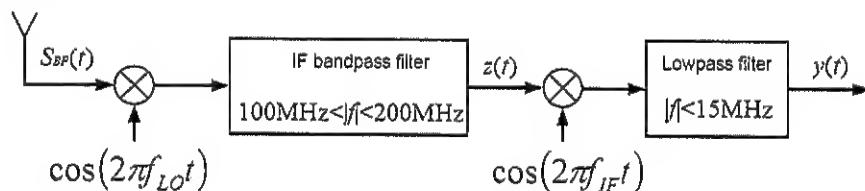


Figure Q4.2

- (i) Draw the magnitude spectrum  $|Z(f)|$  of the IF signal  $z(t)$  at the input of the second mixer in the range of  $-250\text{MHz} \leq f \leq 250\text{MHz}$ . Label the axis correctly. [2.5 Marks]
- (ii) Draw the magnitude spectrum  $|Y(f)|$  of the demodulated received signal  $y(t)$  in the range of  $-50\text{MHz} \leq f \leq 50\text{MHz}$ . Label the axis correctly. [2.5 Marks]

Continued...

## Appendix I

### Trigonometric Preliminaries

1.  $\sin(n\pi) = 0, n = \text{integer}$
2.  $\cos(n\pi) = (-1)^n = \begin{cases} 1, & n = \text{even} \\ -1, & n = \text{odd} \end{cases}$
3.  $\sin^2 x = \frac{1}{2}(1 - \cos 2x)$
4.  $\cos^2 x = \frac{1}{2}(1 + \cos 2x)$
5.  $\sin x \sin y = \frac{1}{2}[-\cos(x+y) + \cos(x-y)]$
6.  $\cos x \cos y = \frac{1}{2}[\cos(x+y) + \cos(x-y)]$
7.  $\sin x \cos y = \frac{1}{2}[\sin(x+y) + \sin(x-y)]$

$$\sin \theta = \frac{1}{2j} [e^{j\theta} - e^{-j\theta}]$$

$$\cos \theta = \frac{1}{2} [e^{j\theta} + e^{-j\theta}]$$

$$x \cos(ax) dx = \frac{x \sin(ax)}{a} + \frac{\cos(ax)}{a^2}$$

$$x \sin(ax) dx = \frac{-x \cos(ax)}{a} + \frac{\sin(ax)}{a^2}$$

Continued...

## Appendix II

### Fourier Transform Pairs

$x(t)$	$X(f)$
$\delta(t)$	1
$\delta(t - t_o)$	$e^{-j2\pi f t_o}$
1	$\delta(f)$
$e^{j2\pi f_o t}$	$\delta(f - f_o)$
$u(t)$	$\frac{1}{2} \delta(f) + \frac{1}{j2\pi f}$
$e^{-at} u(t)$	$\frac{1}{a + j2\pi f}$ , for $a > 0$
$e^{at} u(-t)$	$\frac{1}{a - j2\pi f}$ , for $a > 0$
$e^{-a t }$	$\frac{2a}{a^2 + (2\pi f)^2}$ , for $a > 0$
$t^n e^{-at} u(t)$	$\frac{n!}{(a + j2\pi f)^{n+1}}$ , for $a > 0$
$\text{rect}\left(\frac{t}{T}\right)$	$T \text{sinc}(fT)$
$\text{sinc}(2Wt)$	$\frac{1}{2W} \text{rect}\left(\frac{f}{2W}\right)$
$\Delta\left(\frac{t}{T}\right)$	$\frac{T}{2} \text{sinc}^2\left(\frac{fT}{2}\right)$
$W \text{sinc}^2(Wt)$	$\Delta\left(\frac{f}{2W}\right)$
$e^{-\pi t^2}$	$e^{-\pi f^2}$

Continued...

### Appendix III

Fourier Transform Pairs and Properties

$\cos(2\pi f_o t)$	$\frac{1}{2}\delta(f - f_o) + \frac{1}{2}\delta(f + f_o)$
$\sin(2\pi f_o t)$	$\frac{1}{2j}[\delta(f - f_o) - \delta(f + f_o)]$
$\text{sgn}(t) = \begin{cases} 1 & t > 0 \\ -1 & t < 0 \end{cases}$	$\frac{1}{j\pi f}$
$\frac{1}{\pi t}$	$-j \text{sgn}(f)$
$\sum_{i=-\infty}^{\infty} \delta(t - iT_o)$	$\frac{1}{T_o} \sum_{n=-\infty}^{\infty} \delta(f - \frac{n}{T_o})$
$e^{-at} \cos(2\pi f_o t)u(t)$	$\frac{a + j2\pi f}{(a + j2\pi f)^2 + (2\pi f_o)^2}, \text{ for } a > 0$
$e^{-at} \sin(2\pi f_o t)u(t)$	$\frac{2\pi f_o}{(a + j2\pi f)^2 + (2\pi f_o)^2}, \text{ for } a > 0$

Let  $x(t) \Leftrightarrow X(f)$ ,  $x_1(t) \Leftrightarrow X_1(f)$  and  $x_2(t) \Leftrightarrow X_2(f)$ ; and

$a$ ,  $b$ ,  $t_o$  and  $f_o$  scalar quantities.

Linearity	$ax_1(t) + bx_2(t) \Leftrightarrow aX_1(f) + bX_2(f)$
Conjugation	$x^*(t) \Leftrightarrow X^*(-f)$
Duality	$X(t) \Leftrightarrow x(-f)$
Scaling ( $a \neq 0$ )	$x(at) \Leftrightarrow \frac{1}{ a }X\left(\frac{f}{a}\right)$
Time Shifting	$x(t - t_o) \Leftrightarrow X(f)e^{-j2\pi f t_o}$
Frequency Shifting	$x(t)e^{j2\pi f_o t} \Leftrightarrow X(f - f_o)$
Modulation	$x(t)\cos(2\pi f_o t) \Leftrightarrow \frac{1}{2}X(f - f_o) + \frac{1}{2}X(f + f_o)$
Time Differentiation	$\frac{d^n}{dt^n}x(t) \Leftrightarrow (j2\pi f)^n X(f)$
Frequency Differentiation	$(-jr)^n x(t) \Leftrightarrow \frac{d^n}{df^n}X(f)$

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## Appendix IV

Bessel Function Table

$n$	$\beta = 0$	$\beta = 0.05$	$\beta = 0.1$	$\beta = 0.2$	$\beta = 0.3$	$\beta = 0.5$	$\beta = 0.7$	$\beta = 1$	$\beta = 2$	$\beta = 3$	$\beta = 5$	$\beta = 7$	$\beta = 8$	$\beta = 10$
0	1.000	0.999	0.998	0.990	0.978	0.938	0.881	0.765	0.224	-0.260	-0.178	0.300	0.172	-0.246
1		0.025	0.050	0.100	0.148	0.242	0.329	0.440	0.577	0.339	-0.328	-0.005	0.235	0.043
2			0.001	0.005	0.011	0.031	0.059	0.115	0.353	0.486	0.047	-0.301	-0.113	0.255
3				0.001	0.003	0.007	0.020	0.129	0.309	0.365	-0.188	-0.291	0.058	
4					0.001	0.002	0.034	0.132	0.391	0.158	-0.105	-0.220		
5						0.007	0.043	0.261	0.348	0.186	-0.234			
6							0.001	0.011	0.131	0.339	0.338	-0.014		
7								0.003	0.053	0.234	0.321	0.217		
8									0.018	0.128	0.223	0.318		
9										0.006	0.059	0.126	0.292	
10											0.001	0.024	0.061	0.207
11												0.008	0.026	0.123
12												0.003	0.010	0.063
13												0.001	0.003	0.029
14												0.001	0.012	
15													0.005	
16													0.002	
17													0.001	

	$N$		$N$		$N$		$N$
$\beta = 0.05$	1	$\beta = 0.7$	4	$\beta = 5$	10	$\beta = 20$	28
$\beta = 0.1$	2	$\beta = 0.8$	4	$\beta = 6$	12	$\beta = 25$	34
$\beta = 0.2$	2	$\beta = 0.9$	4	$\beta = 7$	13	$\beta = 30$	39
$\beta = 0.3$	3	$\beta = 1$	4	$\beta = 8$	14	$\beta = 35$	45
$\beta = 0.4$	3	$\beta = 2$	6	$\beta = 9$	15	$\beta = 40$	50
$\beta = 0.5$	3	$\beta = 3$	7	$\beta = 10$	17	$\beta = 45$	55
$\beta = 0.6$	3	$\beta = 4$	9	$\beta = 15$	22	$\beta = 50$	61

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